Recent SLR tracking improvements at SGF Herstmonceux

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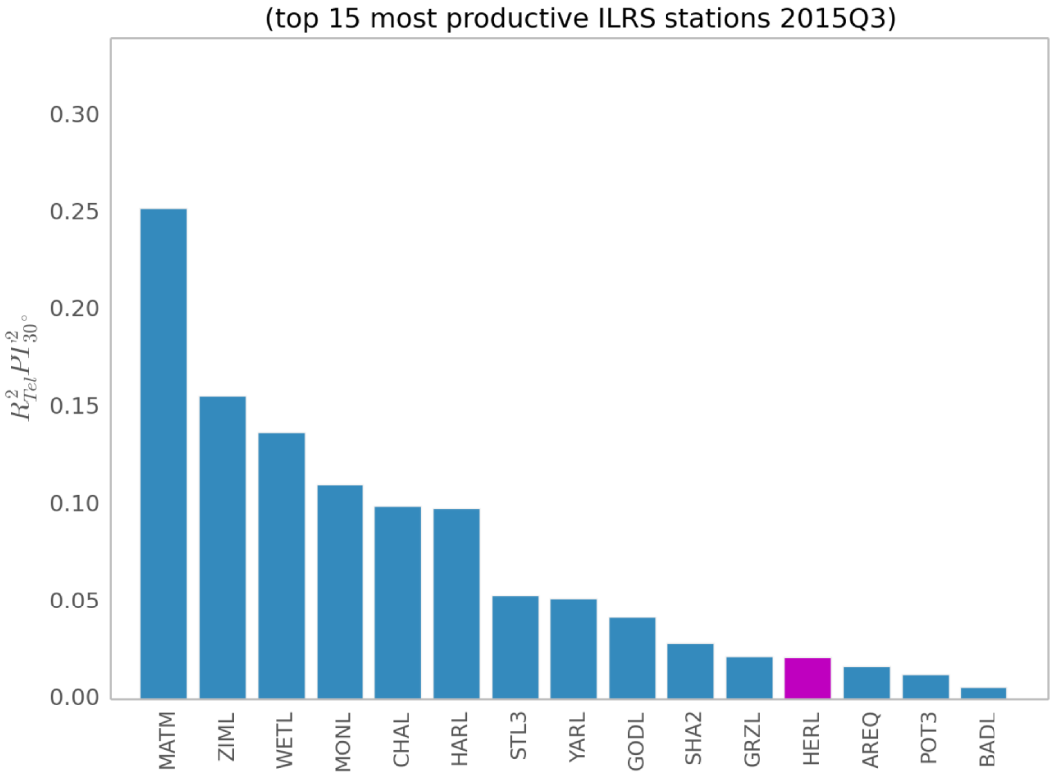
Daytime GNSS tracking difficulties

- Intrinsic weak returns
- High noise rate
- Decreased transmission due to filters
- No nighttime camera
- Pointing
- Turbulence
-

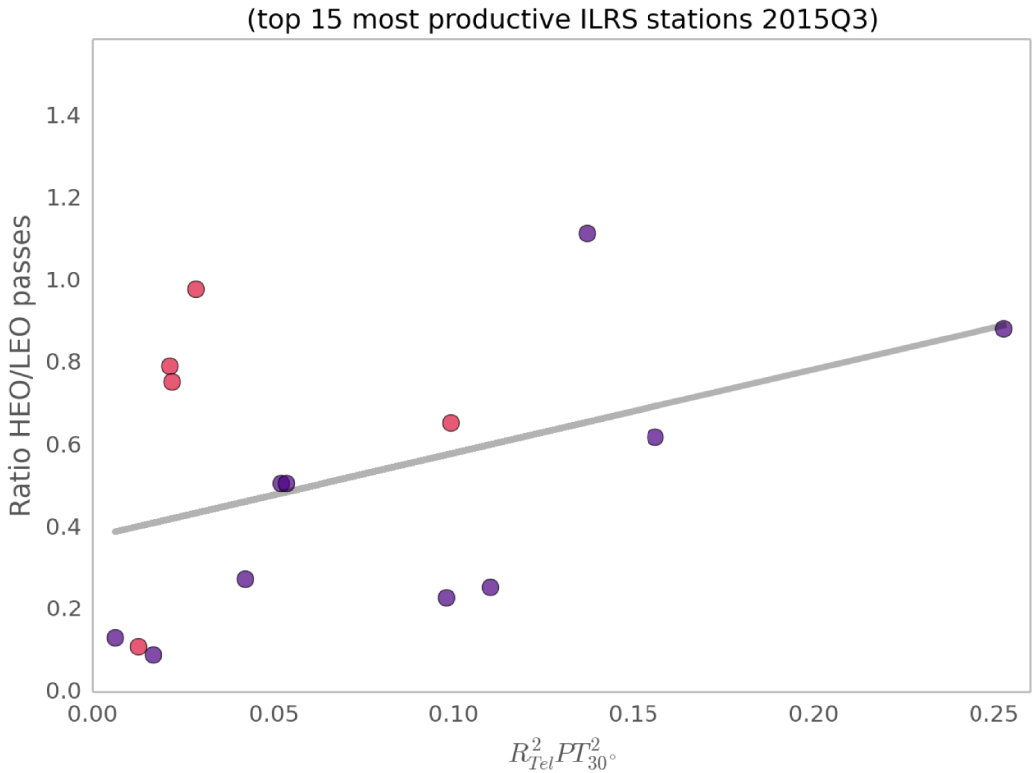


Station parameter that captures (crudely) tracking capabilities:

= *primary radius (m)*

= *average laser power (W)*

=*2-way transmission for 30˚ slant range and clear conditions*



- Stations significantly above or below the line indicate over- and under-performance relative to the expected values
- Reasons for this include scheduling priority differences

Past upgrades at SGF

- Dichroic mirror change
- Coude path optics
- Emitter optics (partial)
- Laser upgrade (0.4mJ@2KHz to 1.1mJ@1KHz)
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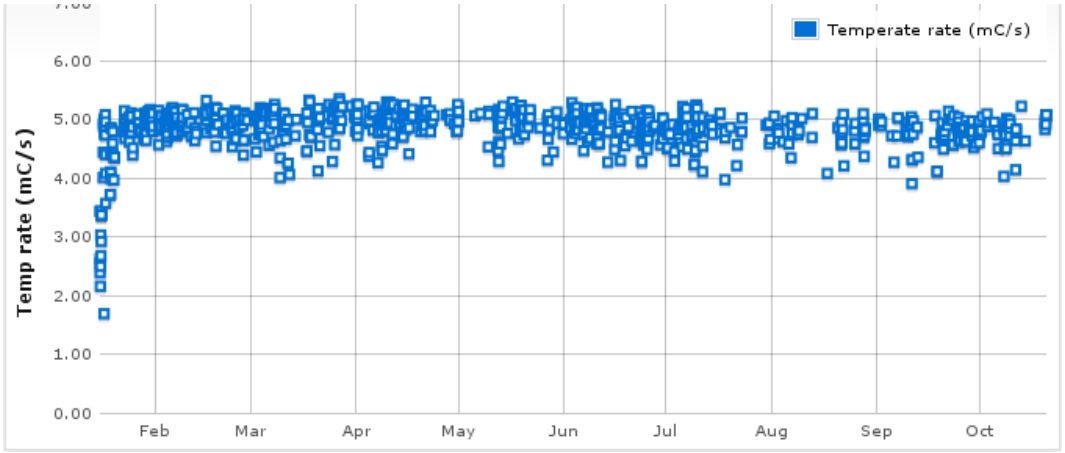
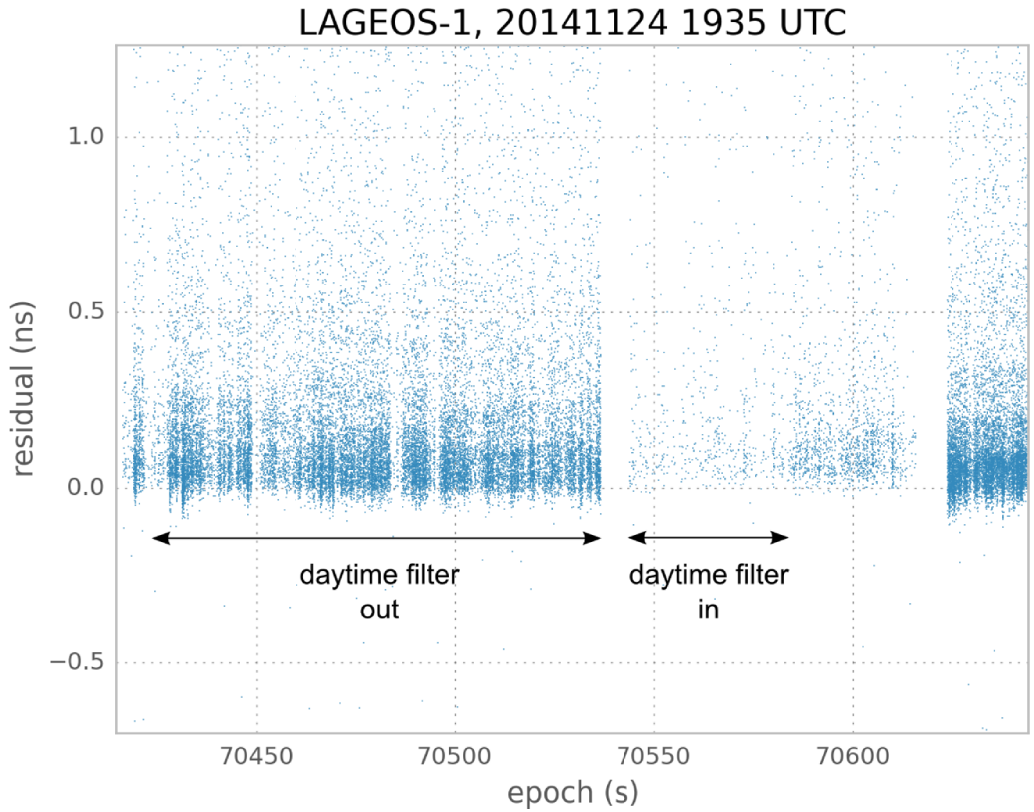
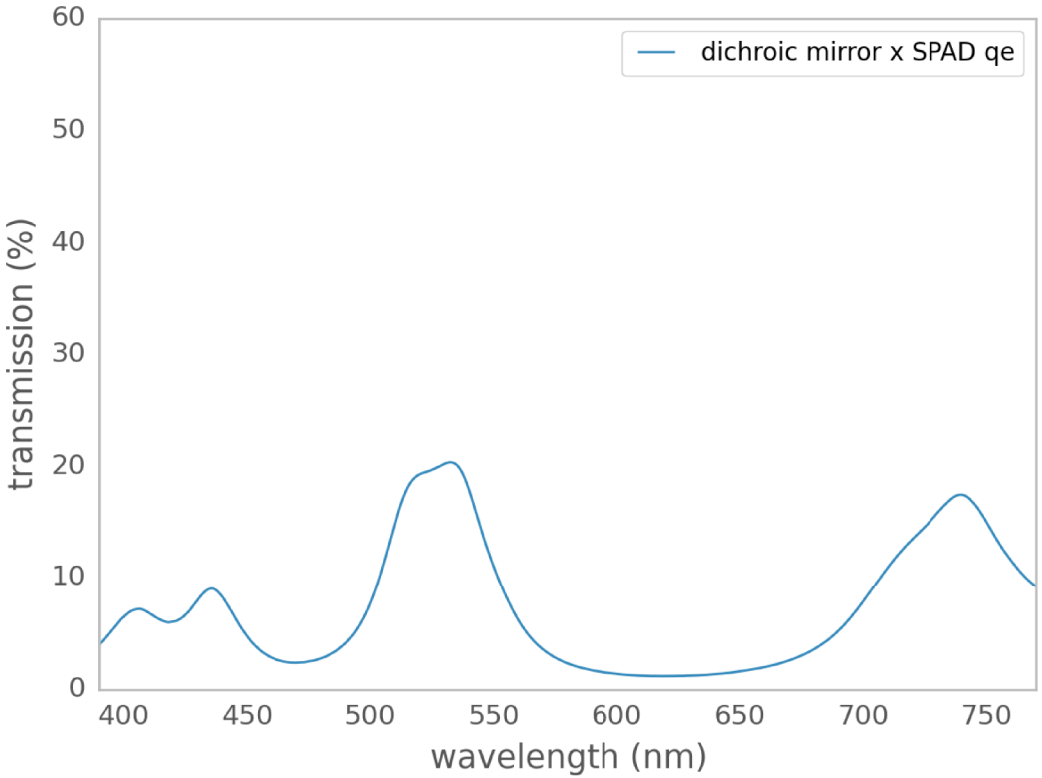


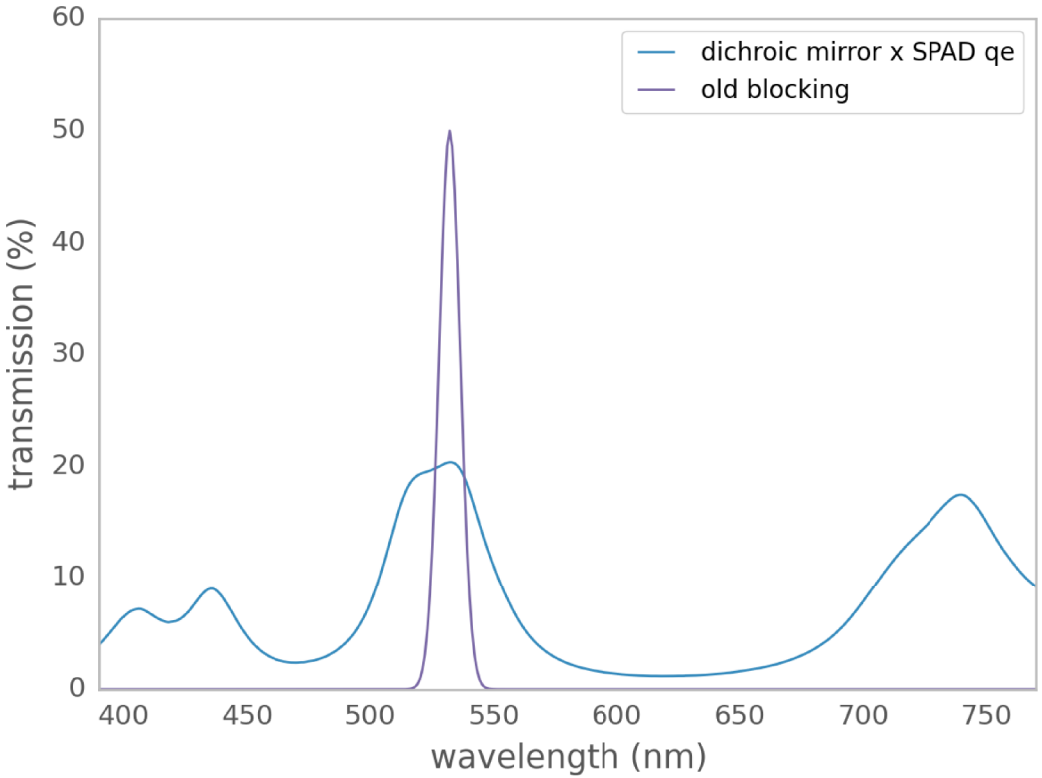
http://sgf.rgo.ac.uk/operations/laserenergy.html

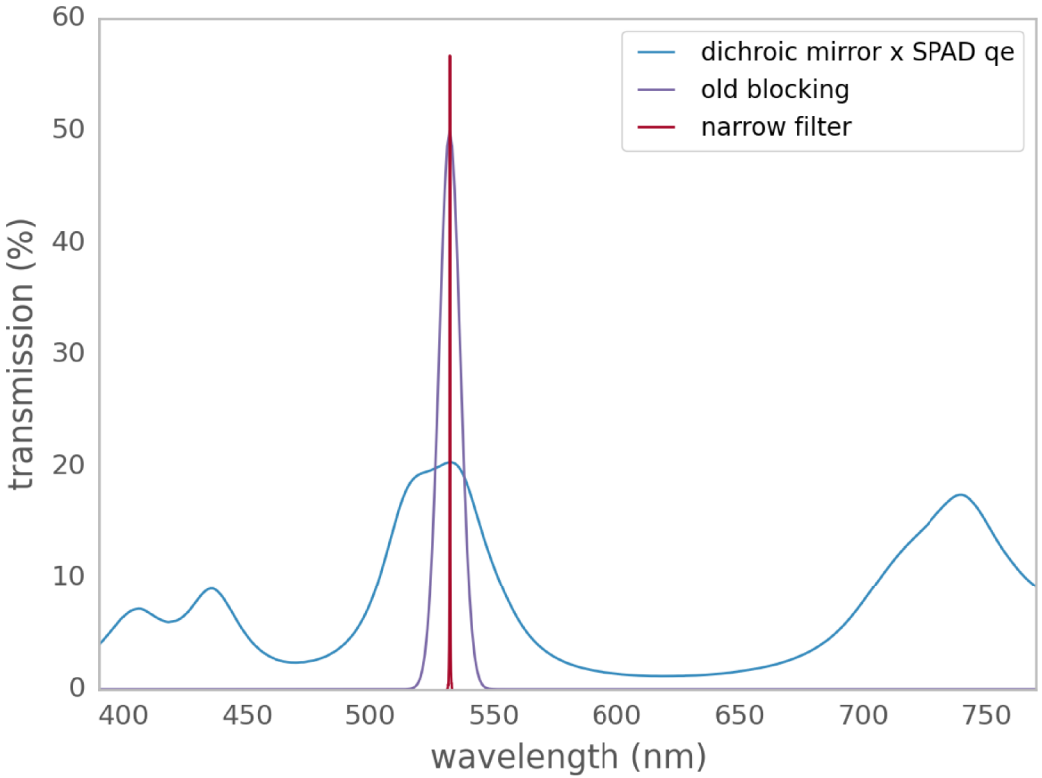


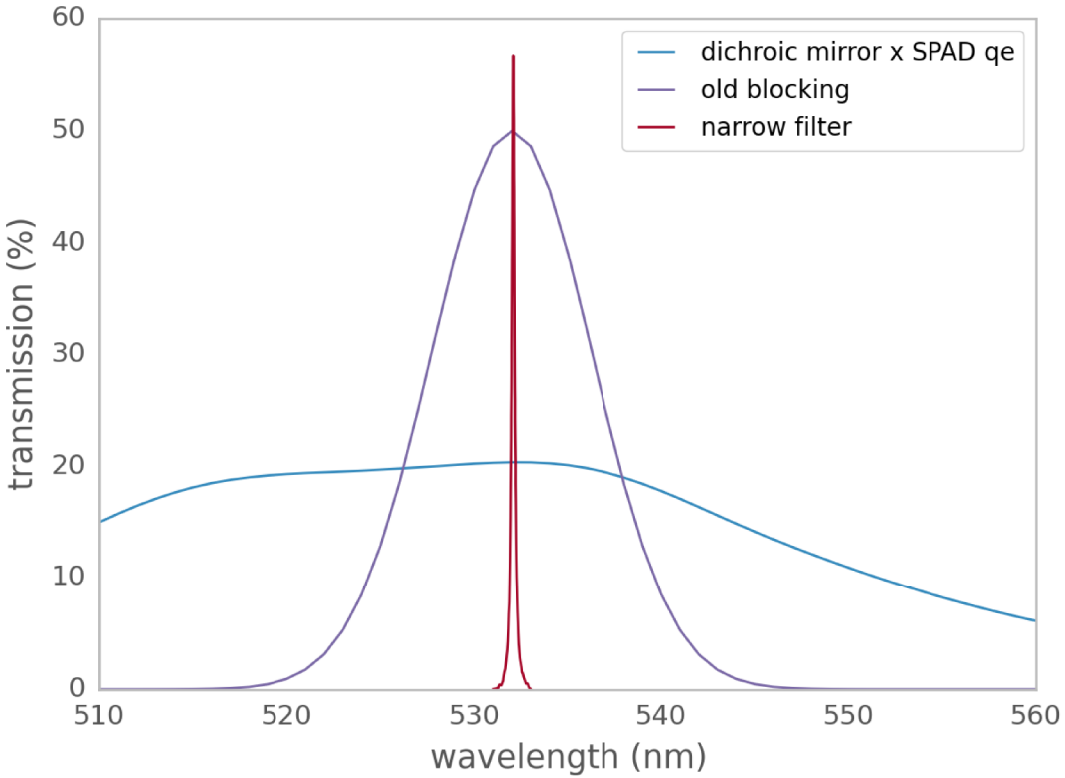
Testing daytime filter transmission

Abysmal performance: ~12.5 % transmission



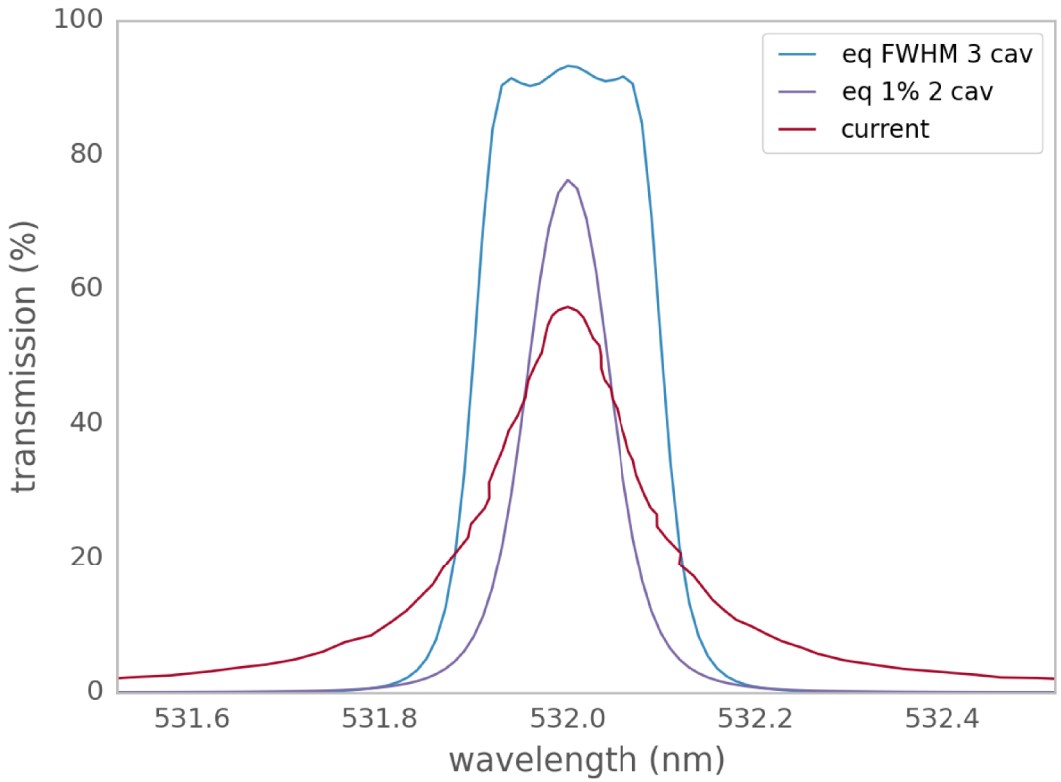




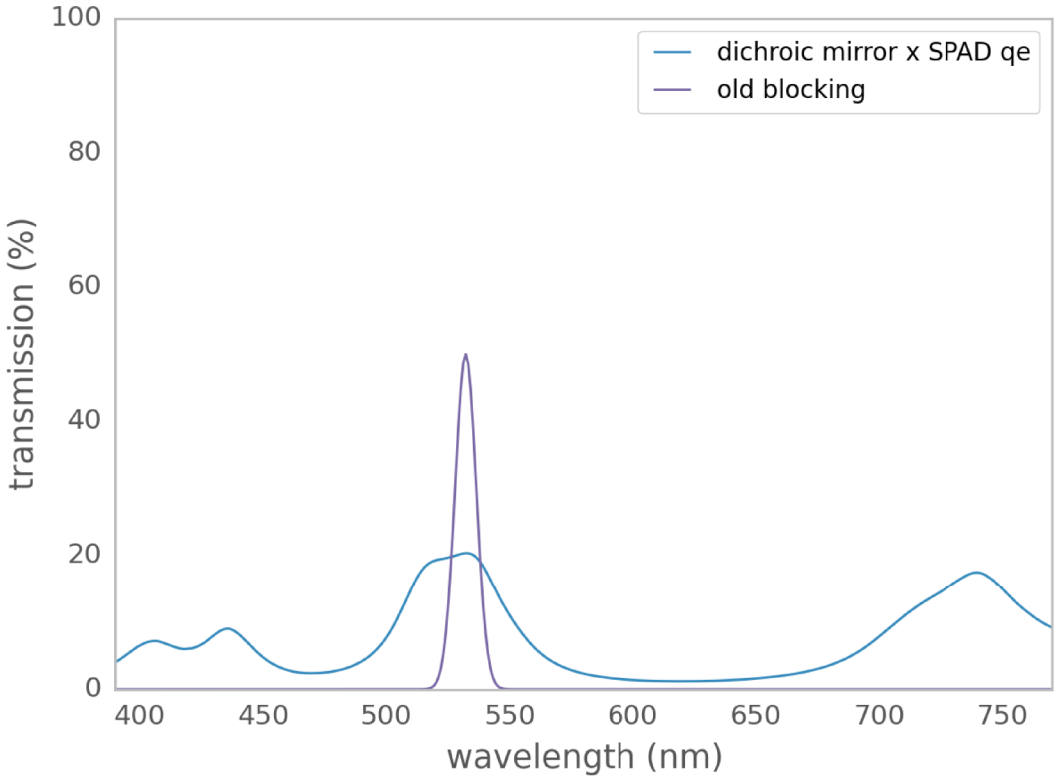


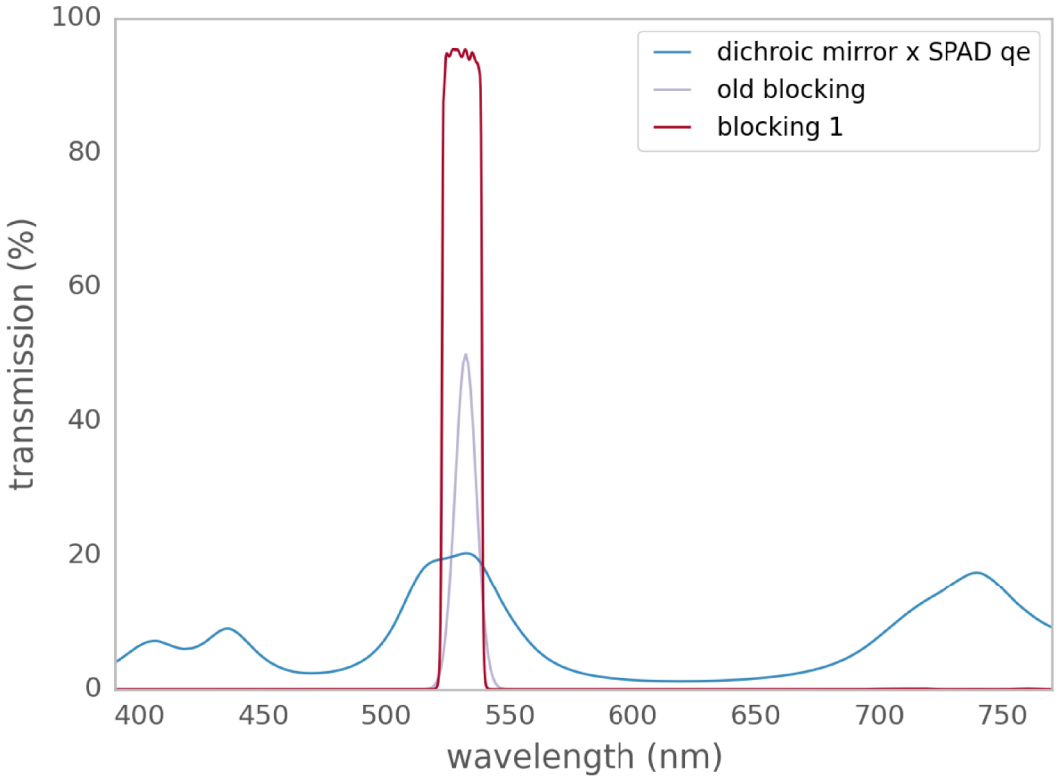
Better alternatives available?

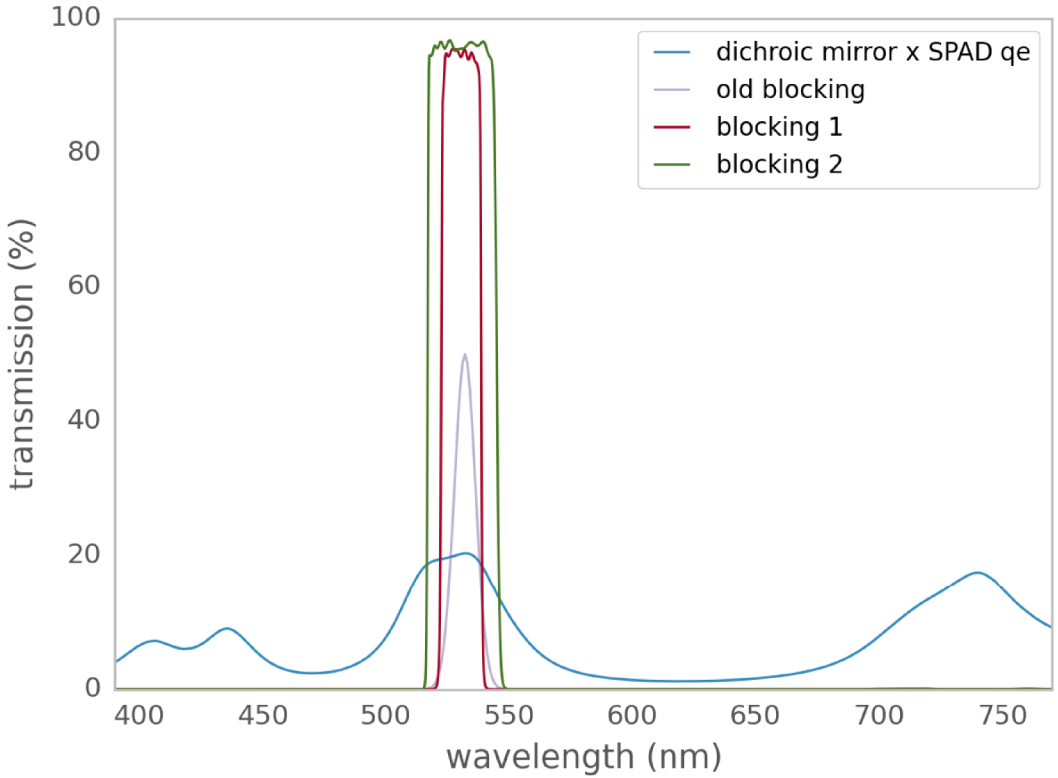
www.alluxa.com (Ultra-narrow bandpass filters)



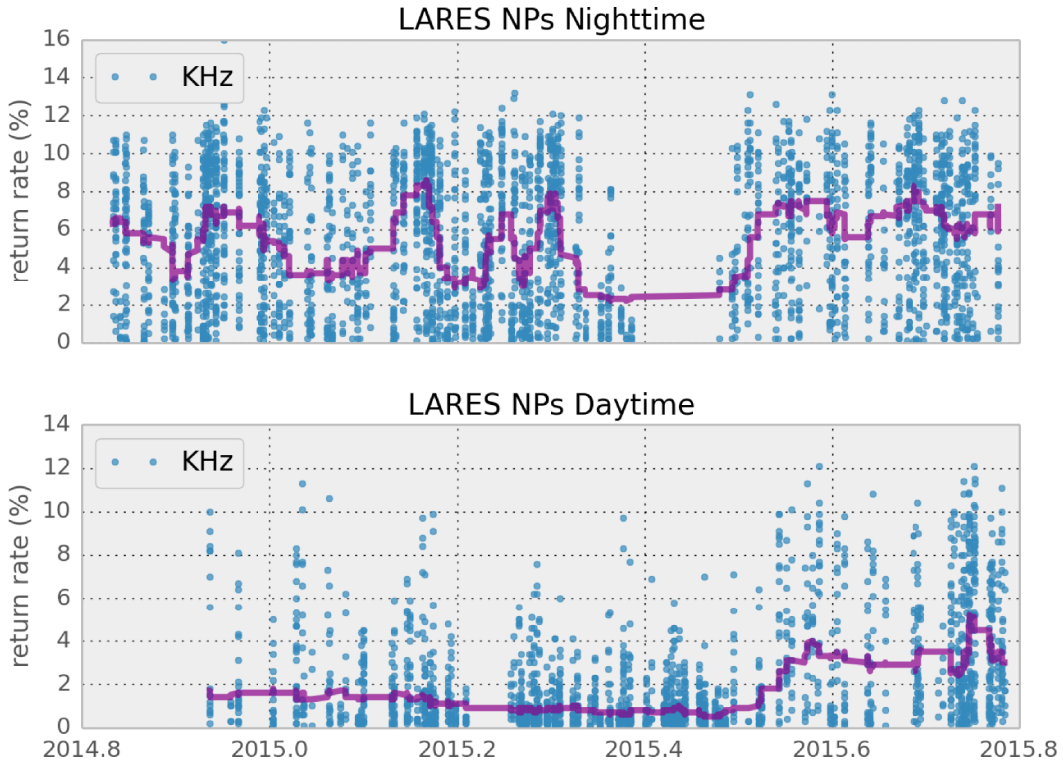
- Extremely good on paper: high transmission, wide band blocking included
- Laser linewidth an issue?
- Manufacturer says: wait for measurement



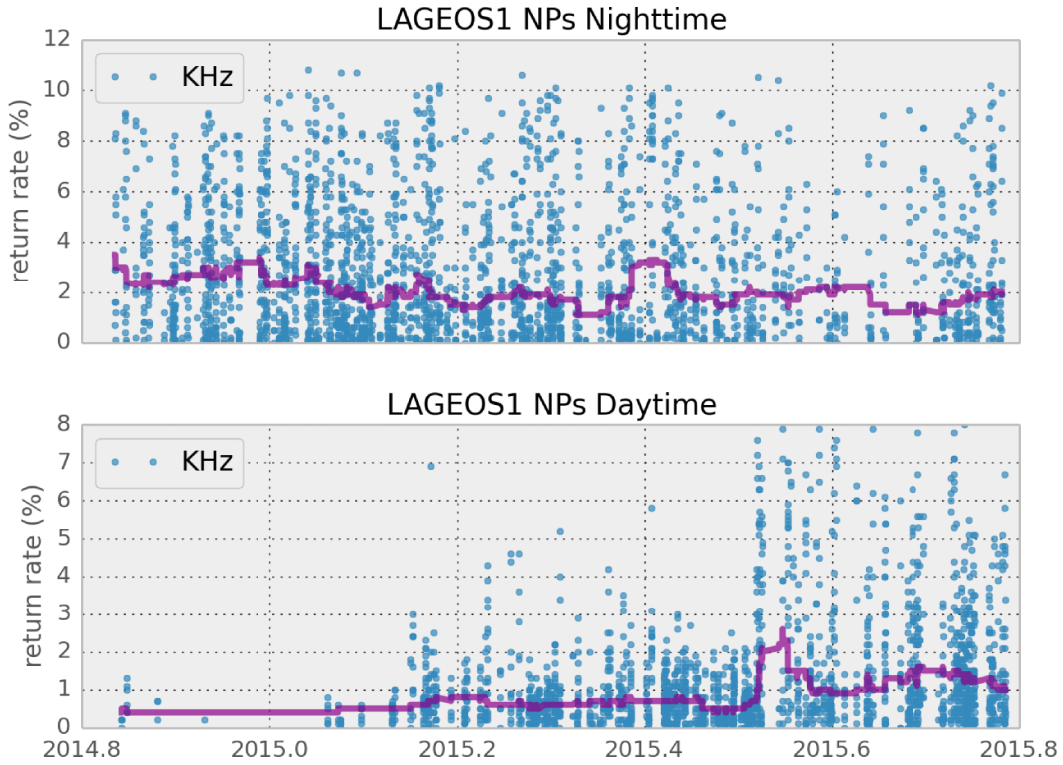




- Dual blocking filter setup (~95% transmission each)
- Actual improvement much higher than expected: old filter underperforming (19-39% transmission)
- Current narrow filter underperforming, barely within spec (~33%)

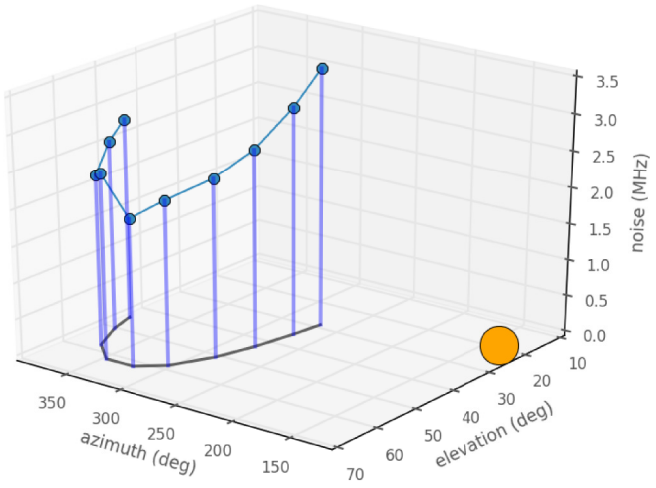


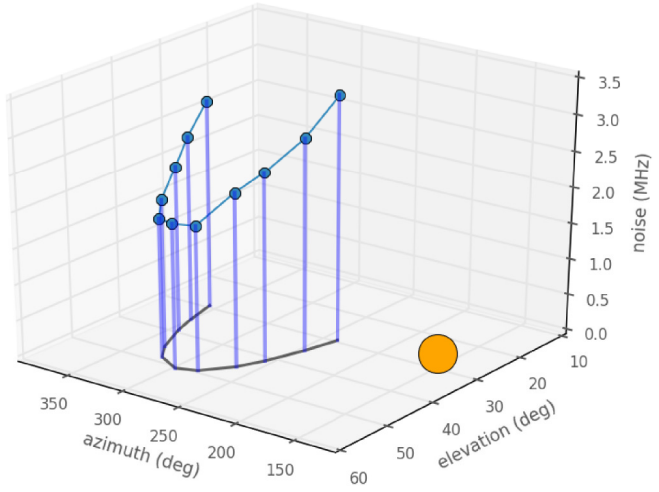
Evidence for improved signal after filter change



Evidence for improved signal after filter change

Noise…





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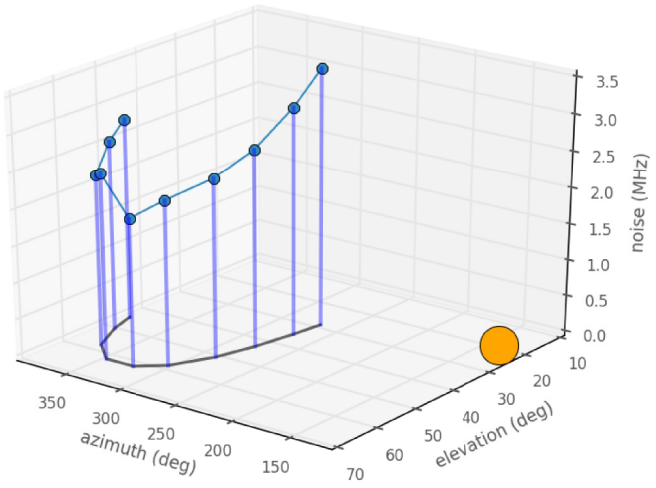

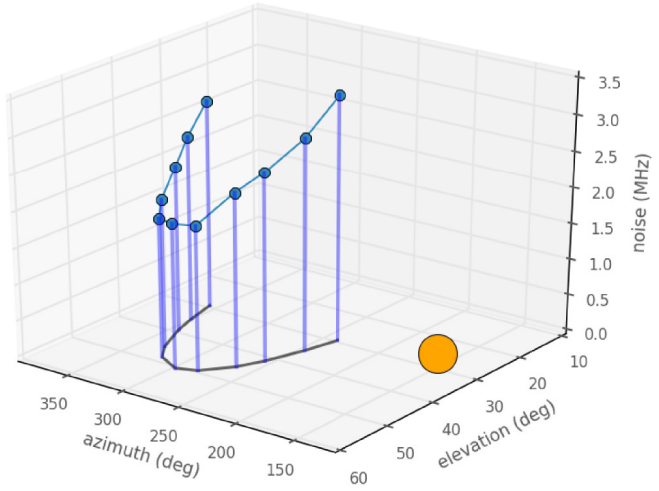

- Noise rate varies greatly with azimuth, elevation, atmospheric conditions and Sun position
- Doubling of noise rates at low elevations typical
- 1-4MHz noise rates fairly common with our setup
- Worse case scenario (really) much worse
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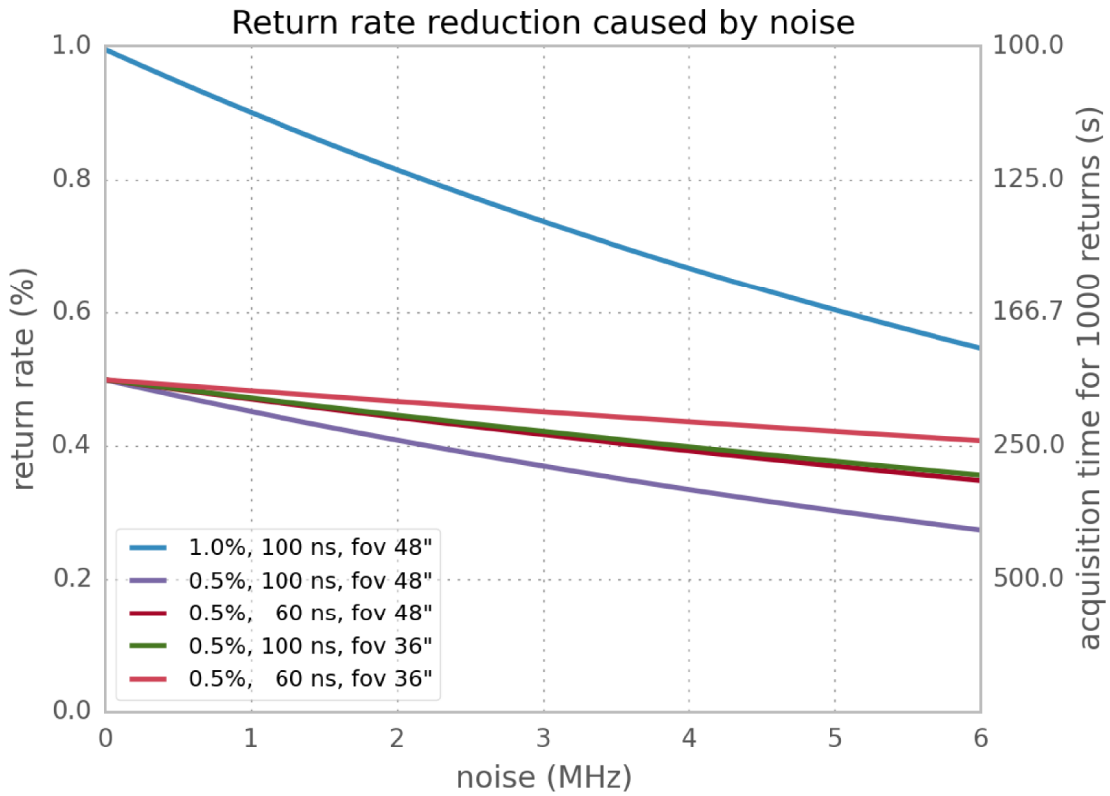
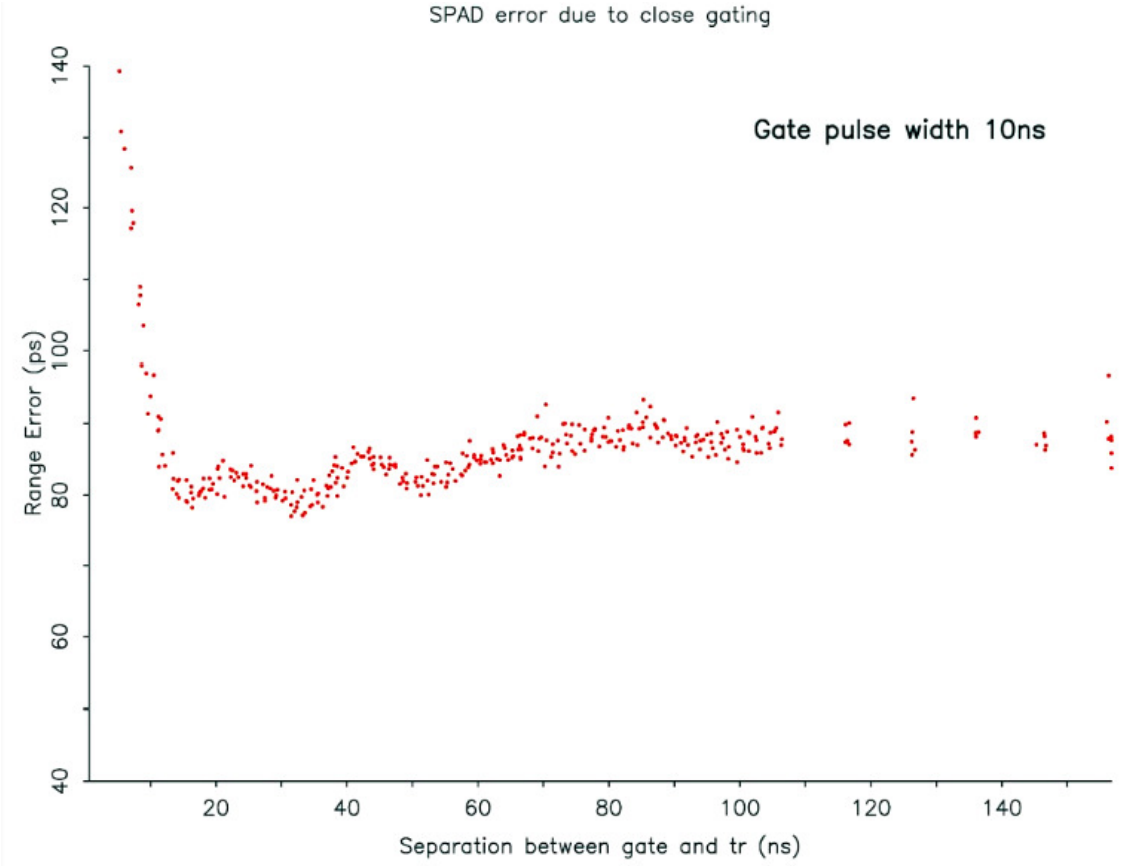


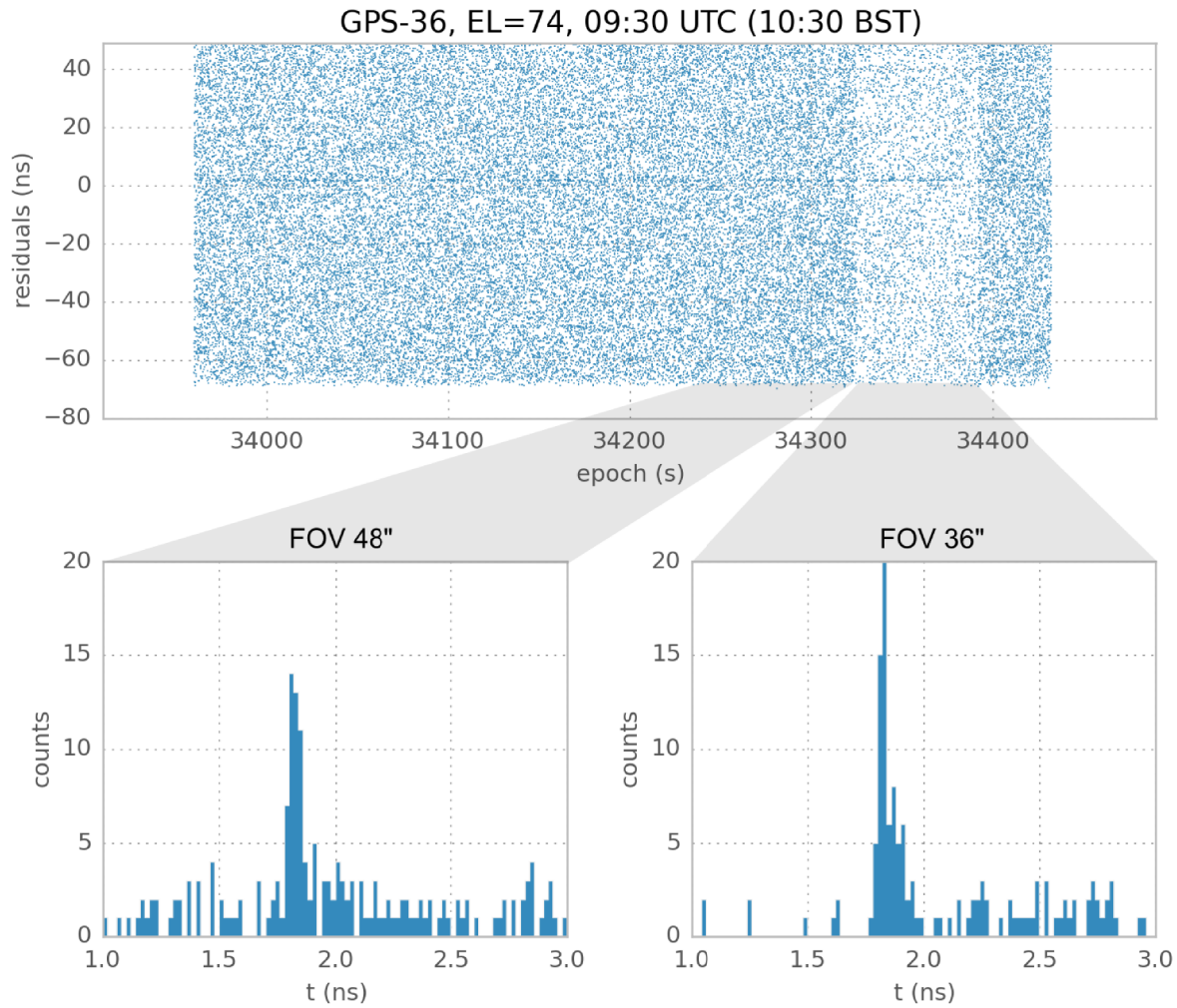
Noise mitigation: temporal and spatial filtering

Worth ensuring optimal operation, especially for weak targets

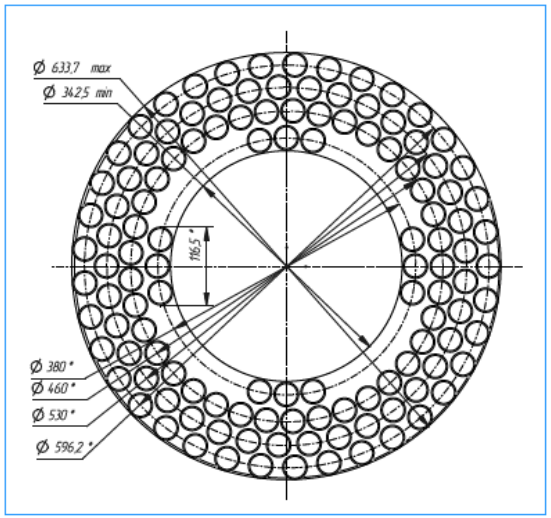


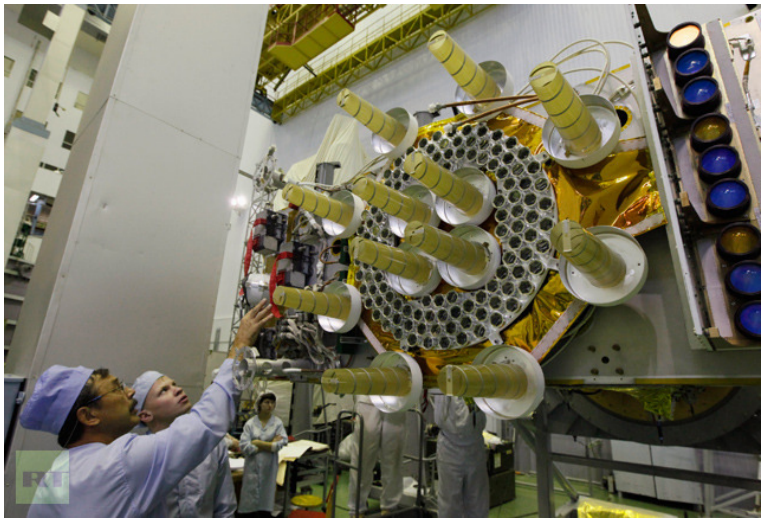
Beware of arbitrary small range gates…

- Found 3 mm error with range gates below ~60 ns
- Must characterise your detector



GLONASS-K1

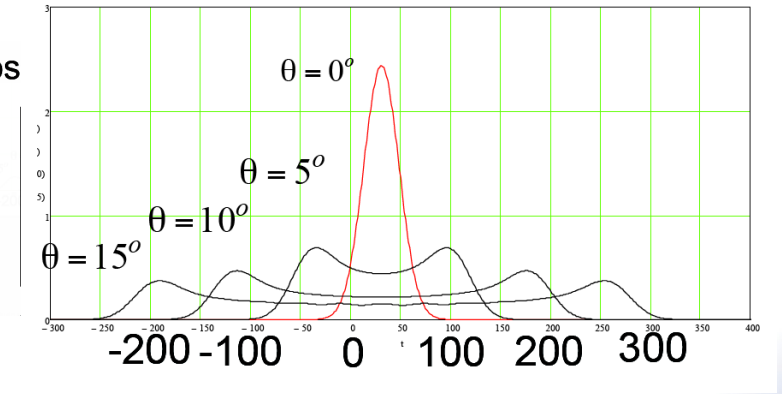




123 items

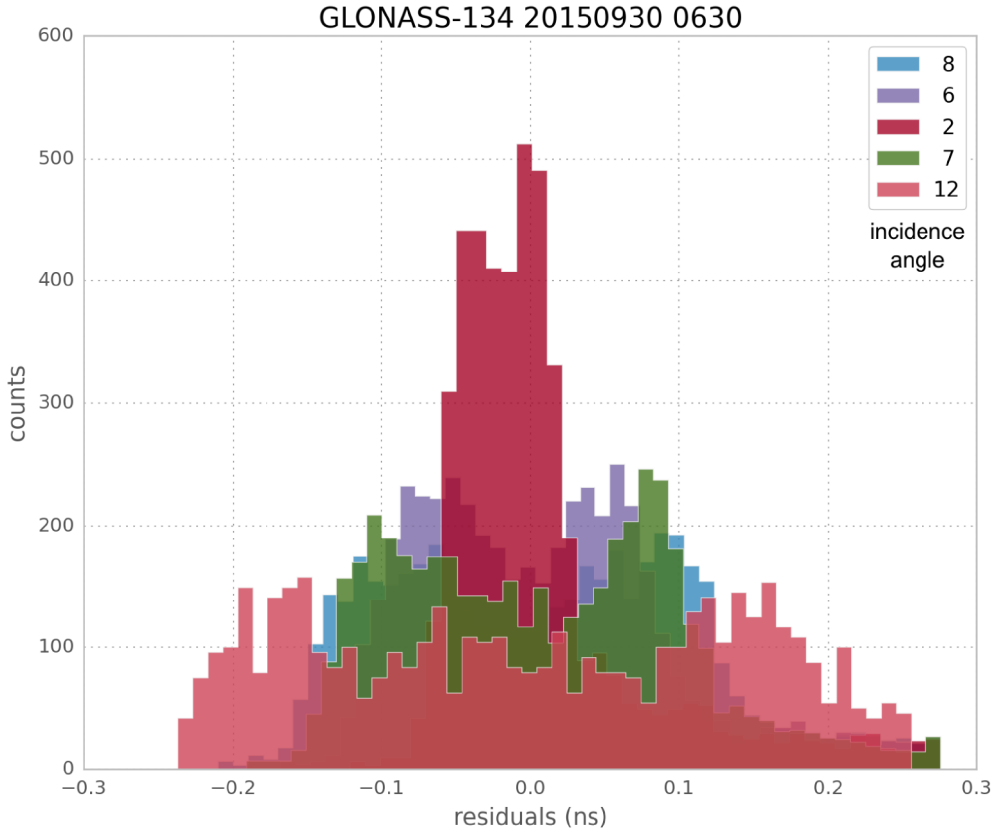
Pulse duration = 50 ps

Angle of incidence	$\theta = 0^o$	$\theta = 5^o$	$\theta = 10^o$	$\theta = 15^o$
RMS of a sing. measur.	6 mm	18 mm	34 mm	51 mm



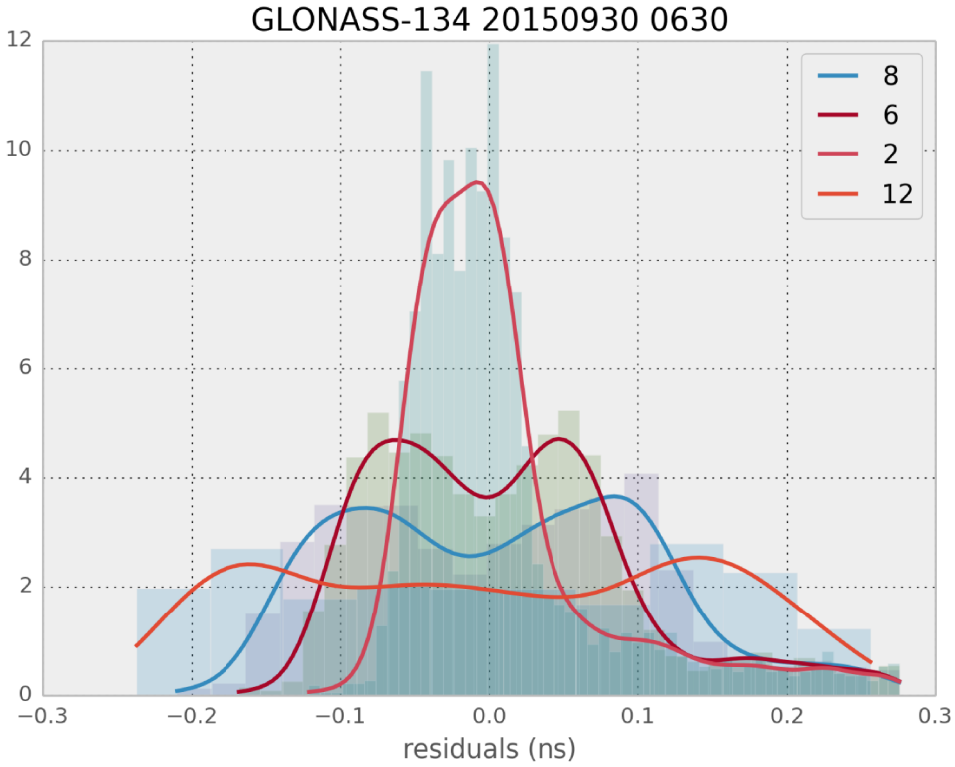
"GLONASS retroreflector systems", Victor Shargorodsky, May 2014:

http://ilrs.gsfc.nasa.gov/docs/2014/glonassretros_shargorodsky_20140501.pdf



Single pass Glonass-134: target signature

Tracking at higher incidence angles (low elevation) increases the apparent size of LRA resulting in shallower signal return distributions.



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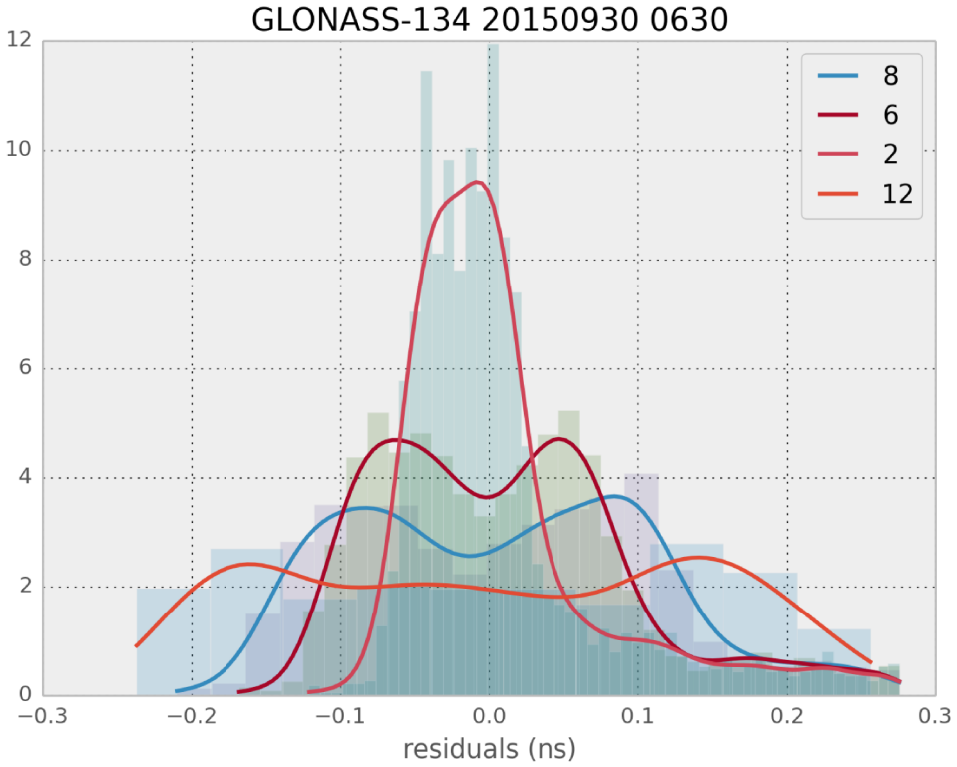

At low elevation:

- higher air-mass
- longer distance
- higher noise
- shallower distribution

Single pass Glonass-134: target signature

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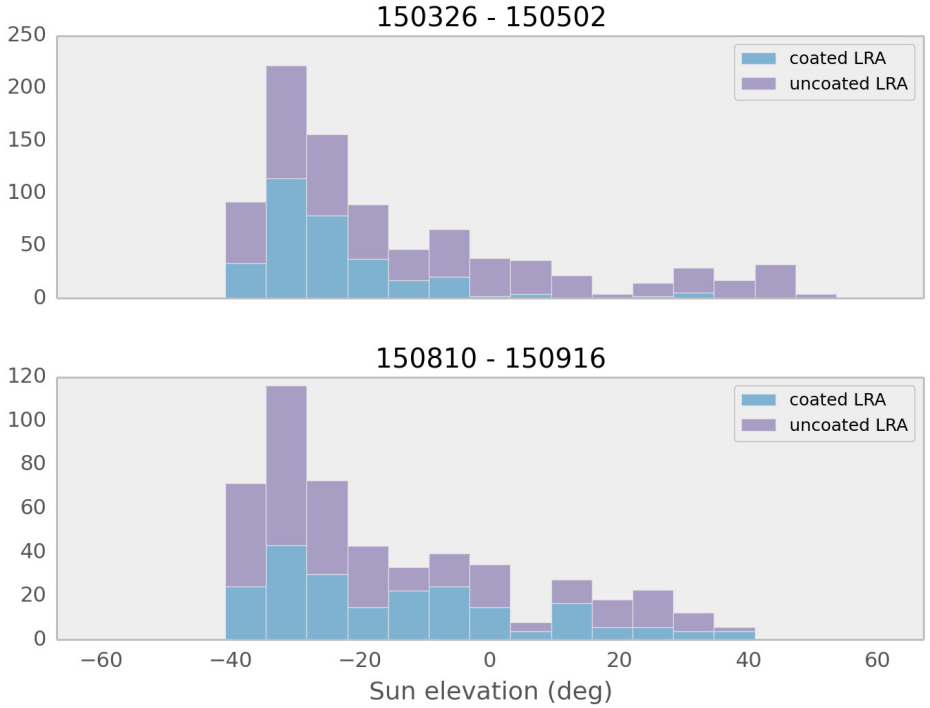
Productivity gains?

Coated vs uncoated GNSS tracking



NPs

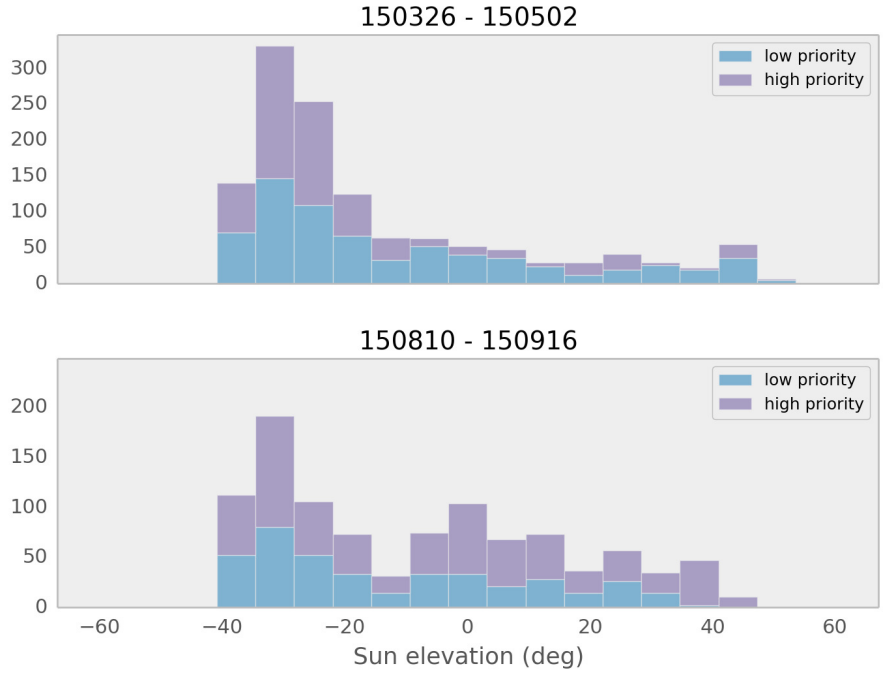
A	168	39.4%	day:	4.2%
B	258	60.6%	day:	33.3%
	426			21.8%

A	114	45.6%	day:	25.4%
B	136	54.4%	day:	25.7%
	250			25.6%

Group A: coated GLONASS

Group B: uncoated GLONASS

Low priority vs high priority GNSS tracking



NPs

A	293	45.9%	day: 31.1%
B	345	54.1%	day: 16.2%
	638		23.0%
A	171	32.4%	day: 34.5%
B	356	67.6%	day: 47.5%
	527		43.3%

Group A: uncoated GLONASS, low-priority

Group B: GLONASS 123, 125, 128, 129, 133, 134, GALILEO 101-4, COMPASS-M3

Conclusions

- Unexpected performance gains may be hiding in your system (suspect everything)
- Best operational practice will help with most challenging targets
- System optimisation increases productivity without sacrificing coverage (there is spare capacity to be exploited)
- Accuracy issues at low elevation: single-photon SLR tracking of GNSS targets ensures centroid of NP distribution refers to nominal LRA offset
- Priority scheduling can make a difference to tracking density of selected S/C
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Thank you